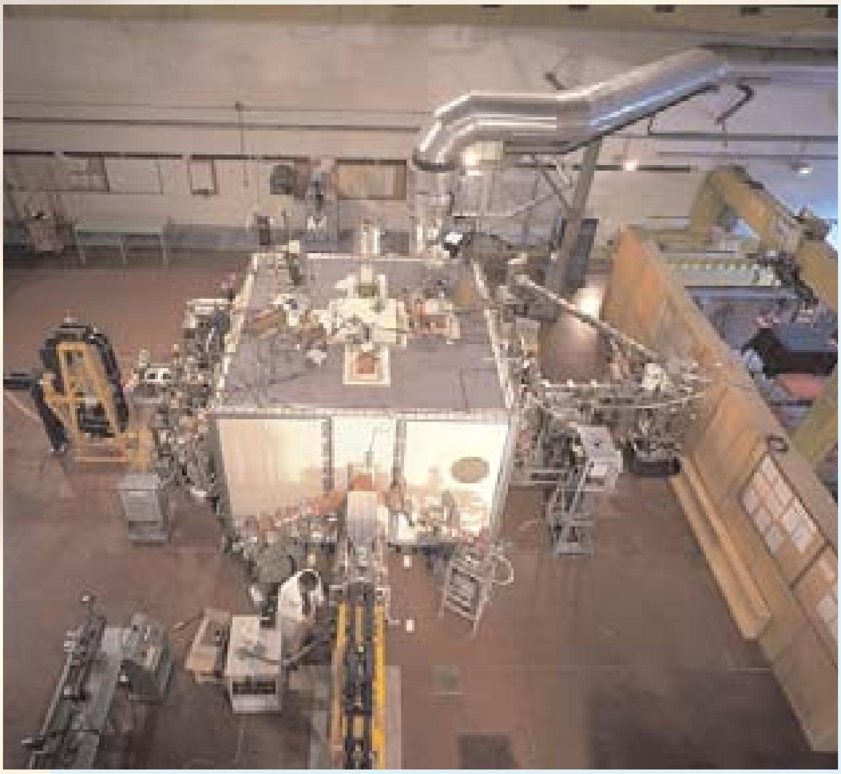
FUSION AND INDUSTRY:
Industrial spin-offs from the fusion programme

EURATOM-ENEA Association on Fusion
Technical and Scientific Division for Fusion

in Italy...

FUSION RESEARCH



Frascati Tokamak (FT)

The goal of the worldwide scientific programmes on fusion research is to harness fusion and thereby provide an inexhaustible, safe, environmentally-friendly and economically competitive source of energy.

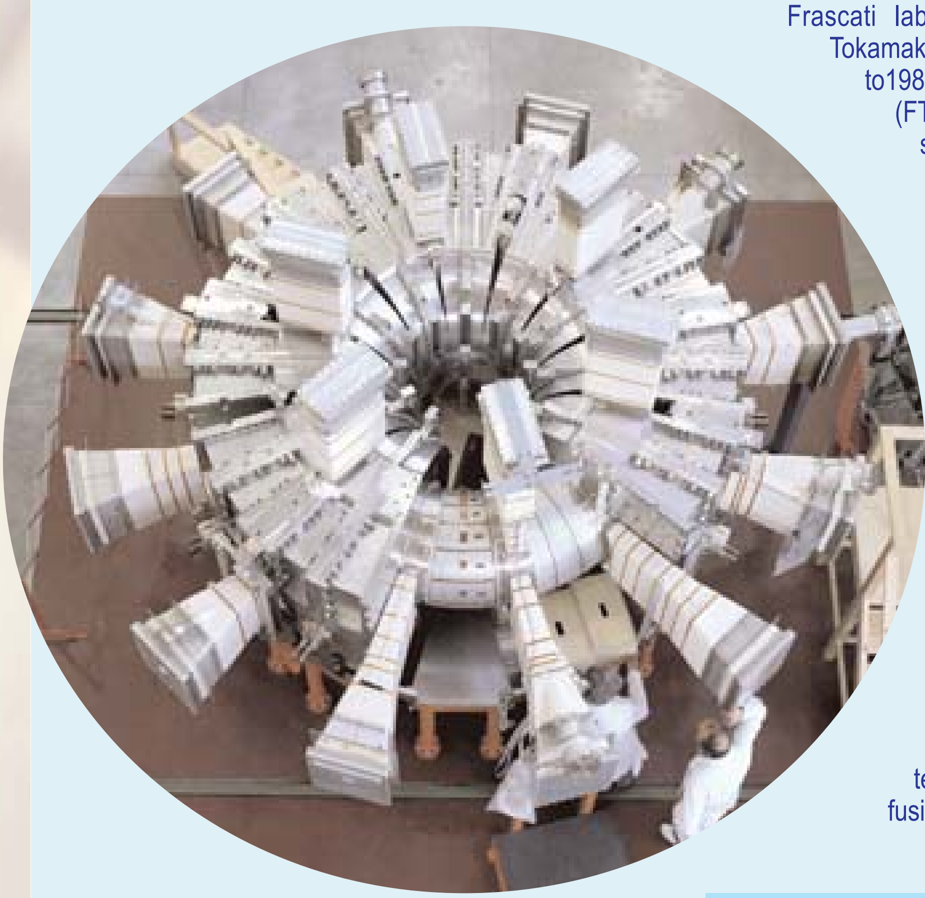
Over the years Europe has gained world leadership in the field of fusion through the construction and the scientific-technological exploitation of experimental plants and facilities.

Italy plays a leading role in the European Fusion Research Programme through the Euratom-ENEA Association on Fusion. The other partners in the Italian Association are the Reversed Field Experiment (RFX) Consortium, Padua, the National Research Council (CNR) Institute of Plasma Physics, Milan and numerous university groups.

The experimental plants constructed at the ENEA Frascati laboratories include the Frascati Tokamak (FT), in operation from 1977 to1989, the Frascati Tokamak Upgrade (FTU) in operation since 1988 for the study of magnetic confinement plasmas, and the ABC laser facility in operation since 1988 for the study of laser-matter interaction.

In line with the FT/FTU machines and currently in the design phase, the IGNITOR tokamak is a compact high-magnetic-field machine whose objective is to reach the self-sustainment of fusion reactions.

Since the 1980s ENEA has also been strongly involved in the development of the technologies required to construct fusion reactors.



Vacuum chamber of Frascati Tokamak Upgrade (FTU)

...and in Europe

The European Fusion Programme is conducted in all the European countries and co-ordinated by Euratom through contracts of association. The high level of co-operation among the associates has ensured the complementarity and full integration of each country's research efforts and their dedication to a common objective.

The European Fusion Development Agreement (EFDA) between Euratom and the associates covers

- the technological activities carried out by European laboratories and industry;
- the multiparty use of the European tokamak – the Joint European Tokamak (JET) – at Culham, UK;
- the European contribution to international collaborations, such as the International Thermonuclear Experimental Reactor (ITER). The objective of the ITER project is to build an experimental reactor capable of demonstrating the scientific and technological feasibility of fusion as an energy source.

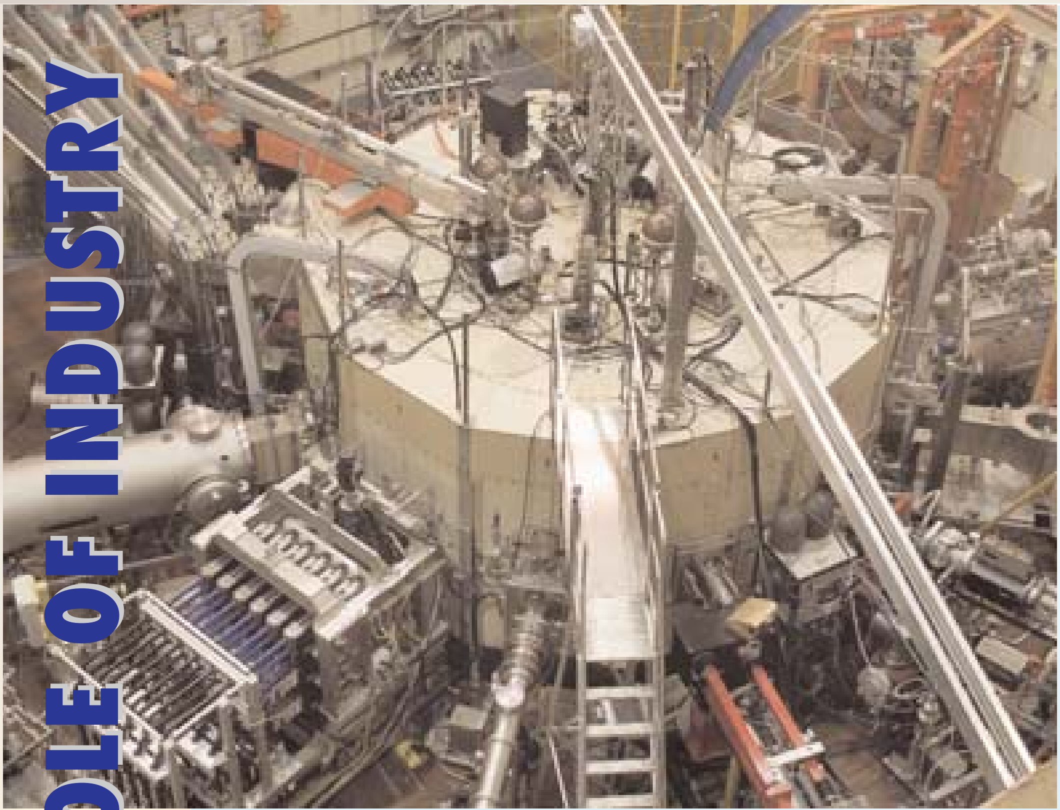
European laboratories engaged in fusion research

Built by Europe in 1982, JET is the largest fusion machine in the world (major radius 3 m, minor radius 1.2 m). In 1997 JET achieved a world record by producing 16 MW of fusion power (65% of absorbed power) and 22 MJ of fusion energy in deuterium-tritium plasma operation. Some of the technologies needed to operate a fusion reactor have been experimented on JET.

Joint European Torus (JET) – Culham, UK

in the realisation

THE ROLE OF INDUSTRY



Frascati Tokamak Upgrade (FTU)

Since the beginning of fusion research, industry has played a fundamental role in realising the experimental machines and apparatus for studying high-temperature plasmas.

For the realisation of the FTU machine ENEA made use of the competence available in Italy. During the design and construction of the machine, more than thirty specialised development contracts were stipulated with industries and universities.

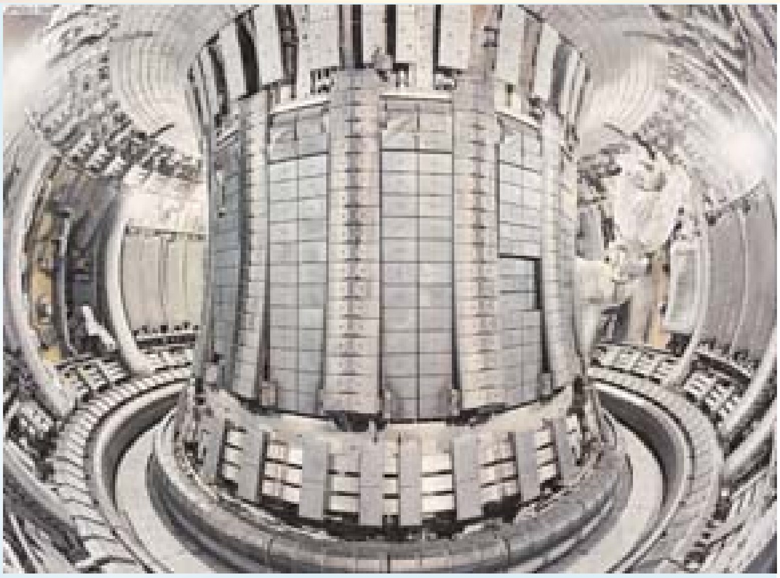
Italian industries produced most of the FTU components and plants after participating in European-wide – and sometimes worldwide - tenders.

Major suppliers and components in the construction of the FTU machine	
Copper	LMI (now Europa Metalli) - Fornaci di Barga *(Lucca)*
Steel	AVESTA *(Sweden)*
Toroidal magnet and suporting structure	ANSALDO *(Genoa)* - FIAT *(Turin)*
Poloidal windings	ANSALDO *(Genoa)*
Central solenoid	INDELVE - Monselice *(Padua)*
Vacuum chamber and limiter	DE PRETTO - ESCHER WYSS (now TURBOMAN) - Schio *(Vicenza)*
Installation equipment	FIAT *(Turin)*
Vacuum and gas-emission plant	PFEIFFER *(Germany)*
Heating tapes	WATLOW *(United States)*
Power supply for tapes	MARELLI *(Milan)*
Liquid nitrogen plant	RIVOIRA *(Turin)*
Auxiliary plants	ABB *(Milan)*
Machine-measurements subplant	LABEN - Vimodrone *(Milan)*
Cryostat	SIMPRES *(Milan)*
Flywheel-alternator-static driver unit	ANSALDO *(Genoa)*
Poloidal field rectifiers	ABB *(Milan)*
Rectifier transforners	ABB *(Milan)*
Plasma start-up system	ABB *(Milan)*
Control system	GAVAZZI IMPIANTI- Marcallo *(Milan)*
Computers	DIGITAL (now Hewlett Packard) *(United States)*
Safety plant	ELECTRON SEA *(Rome)*
8-GHz prototype gyrotron	THOMSON CSF (now THALES) *(France)*
Gyrotron AT power supplies	ABB *(Milan)*
Gyrotron anode modulators	OCEM - S. Giorgio di Piano *(Bologna)*
Buildings and infrastructures	PIZZAROTTI *(Parma)*

# of experimental plants

Thanks to ENEA's promotional activities and to the experience acquired through participation in national projects, Italian firms are now well inserted in the European market and produce components not only for other national machines but also for JET.

The involvement of industry in the fusion programme is now considered imperative for the construction of ITER and the fusion reactor.



Inside the vacuum chamber of JET

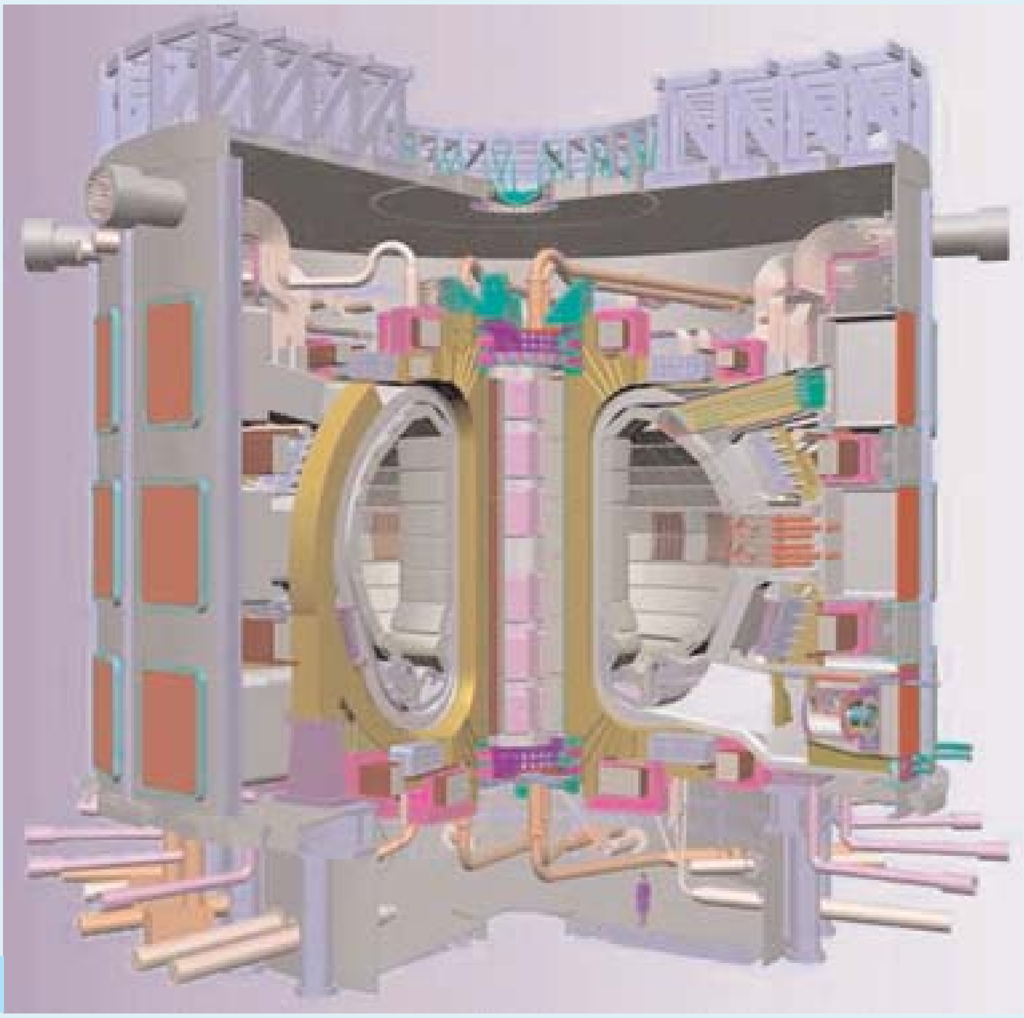
Components of major economic significance produced by Italian industries during/after the construction phase of JET

Vacuum chamber	FLEXIDER *(Turin)*
Central cylinder	BREDA *(Milan)*
Neutron injection box	FILIPPO FOCHI *(Bologna)*
Switchboards	FRATELLI TOZZI *(Ravenna)*
160-kV power supplies for neutron injectors	OCEM - S. Giorgio di Piano *(Bologna)*
150-ton overhead-travelling crane	MAGRINI GALILEO *(Bergamo)*
Control board	ROSSELLI DEL TURCO *(Rome)*
MASCOT telemanipulator	MEKTRON (now ELSAG) *(Genoa)*
400 kV/33 kV transformers	ITALTRAFO - S. Pancrazio Solentino *(Brescia)*
Busbar system	CEME (now AREVA T&D) - Noventa di Piave *(Venice)*
Commutation system for plasma start-up	ANSALDO *(Genoa)*
Sector of test machine	DE PRETTO - ESCHER WYSS (now TURBOMAN) - Schio *(Vicenza)*
Assembly of a sector of the vacuum chamber between two semi-modules of the magnets	RIVA CALZONI *(Bologna)*

Energy for the future...

THE WAY TO FUSION

The next step is represented by ITER, the experimental reactor whose mission is to demonstrate the scientific and technological feasibility of fusion as an energy source. ITER will have double the linear dimensions of JET. It will generate 500 MW of fusion power for about 15 to 30 minutes and, at the same time, exploit in an integrated way all the key components of a fusion reactor. After more than a decade of design and R&D activities carried out by Europe, Japan, the United States and Russia in collaboration, the ITER project is now definitive and the decision to start its construction is being analysed by the partners.



The ITER machine

The construction of ITER, which will take about ten years, will be equivalent to the construction of a power reactor in the technological and engineering effort required. A considerable contribution will be needed from industry, both in conventional fields, such as civil, mechanical and electrical engineering, and in more specialised technological fields, such as the following:

- High-frequency high-power radiofrequency sources and transmission lines
- Plasma-facing components
- Remote handling equipment
- Superconducting materials and magnets
- Diagnostic apparatus for plasma studies
- Components for the fuel cycle
- Materials for the tritium blanket
- Low-activation materials

...Innovations today

With the objective of providing an inexhaustible, safe and economically competitive source of energy, fusion research can contribute in the future to substantially reducing our reliance on fossil fuels, which would go to securing Europe's energy supply and also greatly benefit the environment. In the meantime the work on fusion is providing an enormous contribution to scientific and technological progress.

In Italy, for example, the construction of FTU and JET, the experimental work on these machines and the R&D on the design of ITER and IGNITOR have required the definition of innovative technologies and the continuous involvement of numerous small, medium and large sized enterprises.

In the effort to develop fusion technologies the policy has been to invest in the lines of activity based on consolidated competence inside the laboratories but also liable to involve national industries and find wider applications even outside the fusion field.

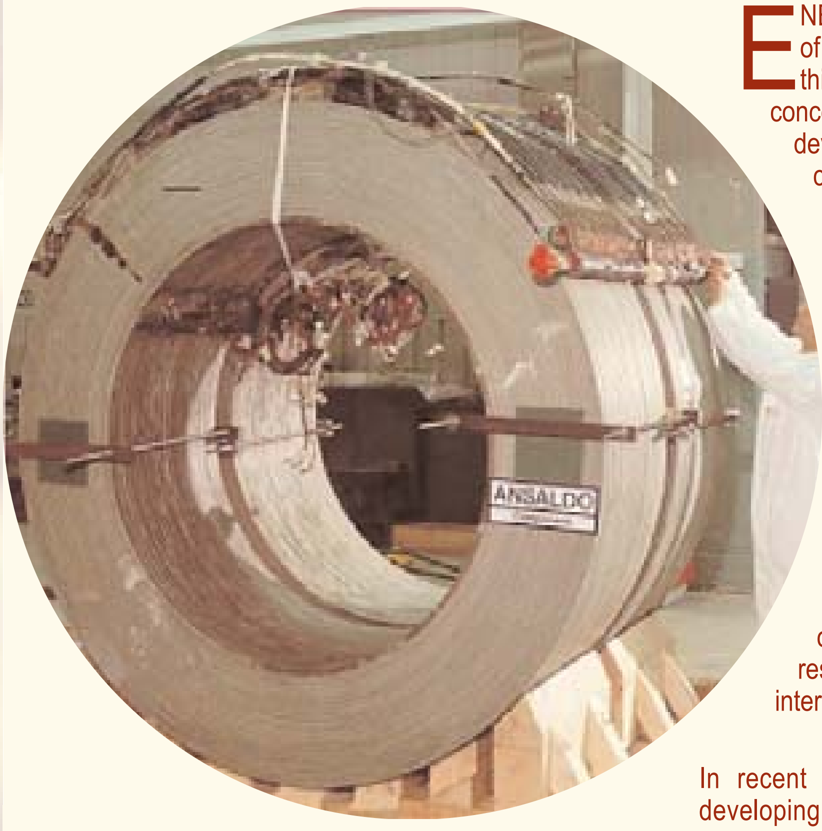
Collaborations have been established with industrial partners in diverse fields, among which:

- Superconductivity
- Joining/deposition materials and technologies
- Advanced instrumentation
- Microwave sources and transmission lines
- Power electronics
- Robotics/optics
- Radiation sources

The fusion activities in these fields can lead to spin-offs with applications in numerous areas outside the boundaries of fusion. Some of these applications are reported in the following. Also illustrated is the potential of the know-how and competence available at ENEA.

at low temperature...

SUPERCONDUCTIVITY



First large-dimension Nb-Ti superconducting magnet designed and built in Italy by ENEA, Europa Metalli and Ansaldo in 1980 for the SULTAN Test Facility – Villigen, Switzerland

ENEA has been carrying out R&D in the field of applied superconductivity for more than thirty years. The main lines of activity concern the development of superconducting devices, strands and cables, the design of conductors and magnets for large-scale applications at high magnetic fields, and studies and experimental work on the stability and operational margins of conductor/coil prototypes.

These activities have been conducted in close collaboration with industry right from the start. Encouraged and stimulated by the fusion programme, Italian industry (Ansaldo and Europa Metalli) entered into the manufacture of components and large superconducting magnets, obtaining excellent results in the fields of research and medical diagnostics at an international level.

In recent years the main focus has been on developing the ITER Nb_3Sn and NbTi superconducting magnets, which will have to operate with currents of 40-70 kA in magnetic fields of 13.5 T. ENEA coordinated all the European development work as well as the tests on the 1:1 scale prototypes, which have a Nb_3Sn cable-in-conduit conductor, forced-flow-cooled with liquid, helium. The Nb_3Sn superconducting cable for the ITER central solenoid was fabricated entirely by Europa Metalli, while the insertion of the cable in the steel jacket was done by Ansaldo. Ansaldo also participated in the European consortium for the manufacture of the toroidal magnet prototype.

The industries engaged in this field can take advantage of all the scientific and technological expertise and equipment available. For example, OCEM of Bologna has been commissioned by CERN to manufacture and assemble the 2100 by-pass diodes for quench protection of the dipole and quadrupole superconducting magnets of the Large Hadron Collider. The electrical characterisation of the diodes at cryogenic temperatures is being performed by ENEA at the Frascati laboratories.

The conductor produced by Ansaldo for the ITER central solenoid model coil by insertion of a cable, fabricated by Europa Metalli, in a steel conduit, followed by compaction

...at high temperature

ENEA is also involved in the development of high-temperature superconductivity. The prospects for application in the fields of energy transport/distribution and electronics in the short term are promising.

From the competence available at the laboratories, Italian industries working in this field receive the necessary scientific support in terms of know-how, instrumentation and advice through specific collaborations and contracts.

Flexible tape in Ni-V non-magnetic alloy characterised by strong preferential orientation and the absence of ferromagnetism, developed as support for high-temperature superconductors (YBCO) – ENEA patent

Some past examples are:

- development of methods of producing yttrium-barium-copper-oxygen (YBCO) superconducting tapes by thin-film deposition, to be applied in energy transport cables for Pirelli Cavi & Sistemi;
- collaboration with Pirelli Labs to study the use of MgB_2 for applications in superconducting electronics (SQUID, Josephson junctions), through depositing MgB_2 films on crystalline substrates;
- collaboration, again with Pirelli Labs, to study adsorption/desorption processes of hydrogen in substrates of metallic storage material (e.g., manganese) and catalysers (e.g., palladium), with the aim of storing hydrogen for electric automobile engines;
- collaboration with Edison Termoelettrica SpA to develop an innovative technique for fabricating bismuth-strontium-calcium-copper-oxygen (BSCCO) cables through depositing thin films of these materials on oxide buffered NiCr or oxide ceramics, or on Ag buffered NiCr tapes.

Composites

MATERIALS

Monolithic silicon carbide and carbon silicon fibre or silicon carbide composite materials, C-SiC and SiC_f-SiC, are used to produce components that have to operate at high temperatures and in hostile conditions. These materials are, in fact, characterised by chemical stability and mechanical resistance at high temperatures, by resistance to abrasion, oxidation and, in general, chemical aggression, so they are used for engine and burner parts in the aerospace industry and in high-temperature heat exchangers. SiC_f-SiC materials are studied in the fusion programme for use as a possible structural material in fusion reactors.

SiC_f-SiC composite preforms

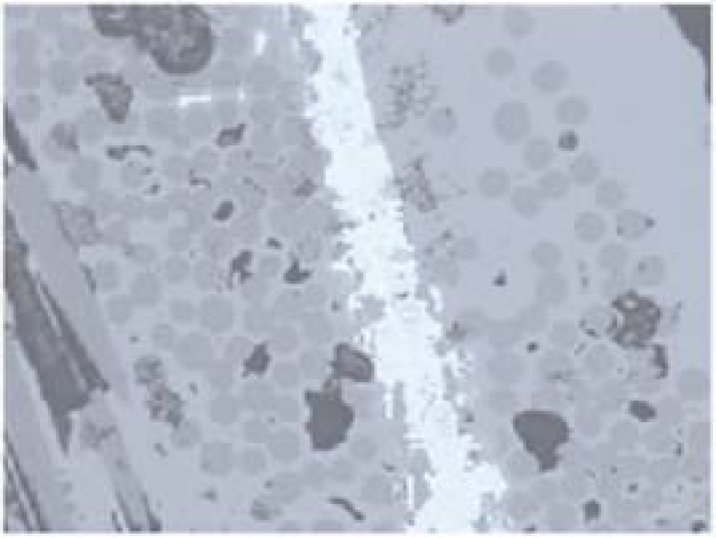
Composites are more resistant than monolithic SiC but have lower values of heat conductivity. How to improve this characteristic of the composites is the subject of intense studies to optimise the fibre-matrix interface, also with the use of three-dimensional textures.

In collaboration with Fabricazione Nucleare (FN) – Nuove Tecnologie e Servizi Avanzati SpA (Bosco Marengo) and Tecnotessile Srl (Prato), ENEA has fabricated preforms in SiC_f-SiC composite of high purity (stoichiometric polycrystalline SiC), high density (up to 2.60 g/cm^3) and high heat conductivity (over 30 W/(mK). The materials produced are pre-industrial level, but the technology can be scaled up to semi-manufactured products with dimensions suitable for industrial applications. The composite material is generally fabricated by infiltrating flat or tubular carbon or silicon carbide fibre textures.

In collaboration with FN, ENEA has perfected and patented a technique to fabricate functionally graded material consisting of a structure of multilayer SiC combined with a continuous-fibre ceramic composite, suitable for making preforms with either flat, curved or tubular geometry. Functionally graded materials have high mechanical resistance, good heat conductivity and gas impermeability.

Functionally graded tubes made of composite material

Joining technologies



Micrograph of SiC_f-SiC composite joint in silicon-titanium eutectic

Monolithic or composite SiC can be economically produced only if the geometry is simple, so particular joining techniques are needed for complex components. ENEA has developed and patented a brazing procedure based on the use of binary alloys, for example Si-Ti or Si-Cr, which have the advantage of melting at high temperatures (at around 1300°C), although lower than the base material, and which react at the interface with the material to be brazed, thereby ensuring high shear strength.

The components of a fusion reactor have to withstand high heat fluxes, and an isostatic-type process known as hot isostatic pressing (HIP) is normally used to weld them. In collaboration with the Centro Sviluppo Materiali (CSM) ENEA has developed and patented an alternative process for complex, hot, solid-state, simultaneous diffusion welding of co-axial objects.

An application of this procedure, known as hot radial pressing (HRP) is shown in the figure. The component is a heat exchanger, consisting of a copper alloy tube which, owing to the high heat flux (up to 20 MW/m^2), has to be protected by a sacrificial material – in this case tungsten – with good thermal contact with the tube itself.

The innovative aspect consists in obtaining the joining by putting the component in a vacuum furnace and then applying internal pressure in the cooling tube channel at the prescribed temperature.

Hot radial pressing device

Palladium alloy membranes and membrane reactors

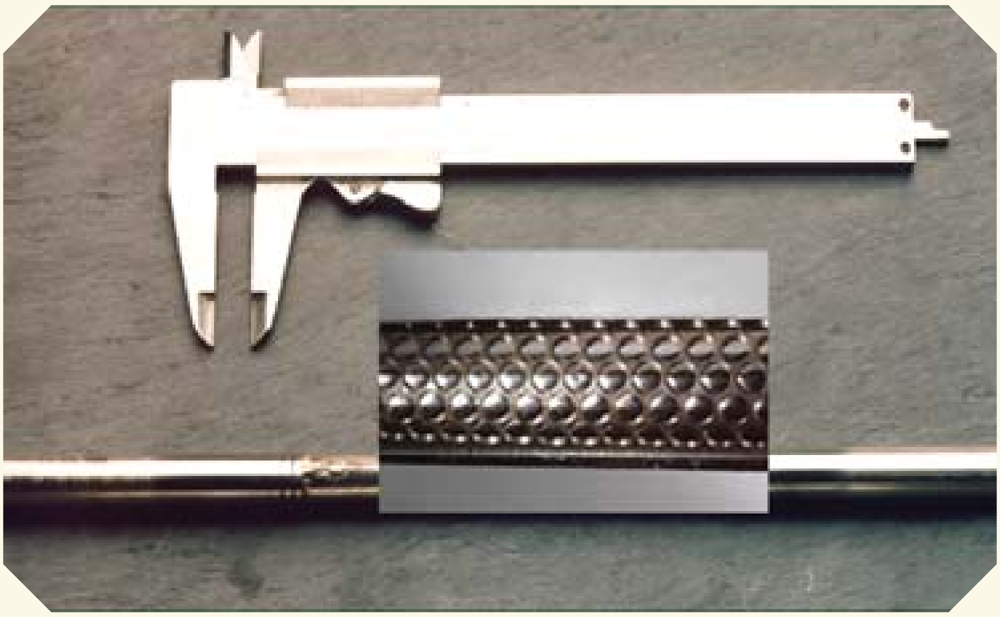
In a reactor burning a deuterium-tritium fuel, these two hydrogen isotopes have to be separated from the other exhaust gases and recovered. This operation can be effected by permeator tubes, which separate the hydrogen isotopes from the gaseous mixtures. The tubes are made of thin completely hydrogen-selective metal membranes developed from palladium alloys.

In catalytic membrane reactors the permeator tube is filled with a specific catalyser to get a reaction producing hydrogen, which, permeating through the membrane, is separated. The technology of palladium alloy membranes and catalytic reactors is applicable in the petrochemical and chemical industries for molecular reforming processes and in the automobile industry for producing hydrogen from hydrocarbons for use in fuel cells in electrically-driven or hybrid automobiles.

The process efficiency increases with decreasing membrane thickness and it is now possible to fabricate permeator tubes from 50-μm-thick membranes, which are completely hydrogen-selective and industrially interesting in terms of reliability and durability. Recently it has been possible to reduce the thickness to 20 μm by using composite metallic membranes with a metal (perforated foils of nickel or steel) support, or layers of low-cost metal coated with palladium. This technology has been patented.

An alternative technology, also patented, has been developed to produce permeator tubes in Pd-Ag (25% Ag by weight) alloy, less than 50-μm thick, by successive stages of lamination and thermal treatment of the Pd-Ag foils, followed by diffusion welding to form the tubular membranes. By using diffusion welding instead of the more standard processes, it is possible to avoid both the presence of defects and the introduction of metallic elements that can contaminate or adulterate the Pd-Ag alloy.

Another application being studied in this line of technology concerns producing industrial electric accumulators with improved safety characteristics through the removal of the hydrogen that can form inside the accumulator while it is being recharged.



Membrane permeator with palladium tube welded between two steel tubes. Insert: magnification of a Pd-Ag membrane on perforated nickel support

Soft-x-ray imaging detector

A micro-pattern gas detector was developed for measuring the x-ray emission from FTU plasmas. The diagnostic is a gas-electron-multiplier (GEM) type detector and is capable of recording digital images in the soft-x-ray energy range between 0.1 and 60 keV. Image acquisition utilises a limited number of pixels (1024) but with high frequency (up to 100 kHz), high sensitivity, contrast, dynamic range and signal-to noise ratio.

The electron signal is collected at the pixel in the single-photon-counting mode, with an independent line for each pixel, which allows photon-energy discrimination as well as image acquisition for different energies. These characteristics make the system absolutely original and innovative. The firm of CAEN (Viareggio) realised the whole data acquisition system, with software developed ad hoc for instrument and image-display control.

The instrument, which is patented, can be applied in the characterisation of extended x-ray sources, in x-ray microscopy (e.g., the study of biological specimens in vitro), x-ray photolithography (e.g., used in the semiconductor and electronic circuit industries), x-ray microtomography (analysis of composite materials, interfaces between different materials, deposition-process control, analysis of defects), x-ray diffractometry (in studies on crystals and macromolelcules).

Systems for measuring inert gas content in complex gaseous mixtures

The studies on palladium-hydrogen systems have led to the development of a system that can be used to measure the inert gas content in complex gaseous mixtures. For example, minute quantities (of the order of 1 ppm) of helium (both ^{4}He and ^{3}He) can be measured in the presence of a high deuterium and/or tritium content by using a standard quadrupole mass spectrometer. The instrument has applications in environmental research - for example, analysis of the ^{4}He content and/or ^{4}He/^{3}He isotopic ratio in fresh or seawater samples. Other possible applications are in the field of volcanology and in the prevention of disasters resulting from seismic events or volcanic eruptions.

MICROWAVE SOURCES AND TRANSMISSION LINES

End converter of main transmission line to the 12 LHCD waveguides of FTU

At FTU three different microwave systems are used for plasma heating and current generation. The systems operate at values of frequency/power equal to:

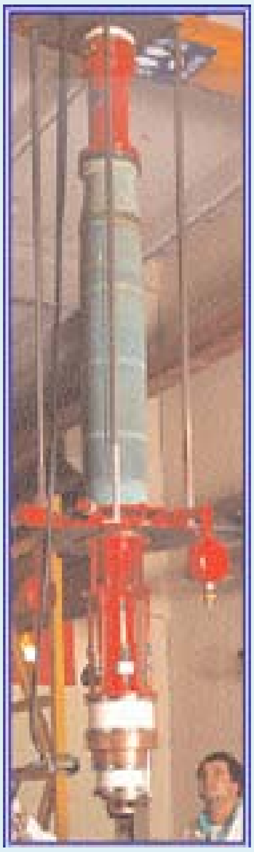
- 433 MHz/1.2 MW ion Bernstein wave – IBW;
- 8 GHz/6 MW lower hybrid heating and current drive – LHCD;
- 140 GHz/2 MW electron cyclotron resonance heating – ECRH.

ENEA designed and supervised the realisation and installation of the systems and at the same time developed innovative components, such as mode converters, circular waveguides, plasma coupling and divider structures (grills, insulating windows).

Two of the systems use gyrotrons as high-power microwave sources. These devices were purchased from Thales Electron Devices (ex Thomson, France) and from Gycom Ltd (Nizhni Novgorod, Russia). Developed in Russia for fusion applications, gyrotrons can also be used in the materials industry for rapid, localised heat treatment of materials with low heat conductivity (polymers, glass, ceramics, semiconductors).

ENEA designed the series control system of the ECRH gyrotrons and the gun-anode modulators and auxiliary power supply for the LH gyrotrons, which were then produced by OCEM (Bologna). Supported by ENEA, OCEM is currently involved in the realisation of an innovative, wholly solid-state high-voltage modulator for the ECRH gyrotrons of ITER.

In addition to the plants in operation on the FTU machine, two 8-GHz plants are available for testing components, one at 25 kW CW and the other at 400 kW for 4-s shots/4 minutes.



One of the gyrotrons used in the LHCD plant of FTU

POWER ELECTRONICS

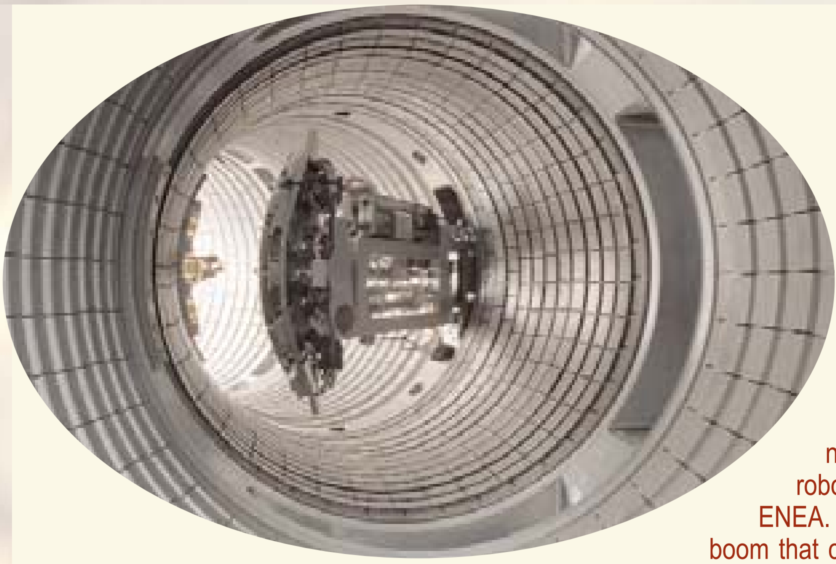
The very high electric power (hundreds of MW) required by experimental fusion plants has to be controlled practically in real time (a thousandth of a second). This is done by using appropriate solid-state power amplifiers.

ENEA collaborated with Ansaldo Sistemi (now Ansaldo ASI Robicon, Milan) in the development and testing of the reference prototype module of the ITER power amplifiers, which have the following characteristics: output voltage equal to 2.5 kVdc, output current equal to 45 kA, fault-suppression capability up to 310 kA without needing switches or fuses. Fault suppression is required to enable the plant to resume normal operation once the cause of the fault has been removed. The prototype was successfully tested up to the maximum current.

Encouraged by the results obtained, Ansaldo ASI Robicon developed a commercial version of the apparatus, which is marketed in standard containers for direct installation. These units are typically 1 kV, 100 kA and have a flexible configuration (series/parallel) to allow modification, at constant power, of the output voltage and current.

Prototype of power amplifier built at Ansaldo for ITER

Intelligent actuators



Installation of a sector of the toroidal limiter inside the FTU vacuum chamber

Working in robotics since the 1960s, ENEA has gained solid experience and know-how in this field. The MASCOT master-slave telemanipulator built in the 1960s has been upgraded continuously (a recent version is still being used at JET). An articulated boom - IVROS - is used to move the components and parts inside the FTU machine. IVROS is a robot with 8° of freedom, which moves autonomously without needing an operator. Recently a new robot – MULTILINK – has been developed at ENEA. It consists of a four-segment articulated boom that can cover an angular track of up to 90° inside FTU.

Metrology and inspection systems

The internal parts and components of a fusion machine have to be periodically inspected by means of special viewing and ranging systems capable of operating in environments that are particularly hostile due to the presence of gamma radiation, the high temperature (>200°C), high vacuum (10^{-8} mbar) and high magnetic field (6 T). ENEA has developed a laser inspection system precisely for this purpose. Known as the in-vessel viewing and ranging system (IVVS), it operates by using an infrared laser beam transmitted through a coherent optical fibre to a probe where a focusing optic and a scanning system deflect the laser beam to obtain complete 3D mapping of the target. A highly accurate image of the target is obtained from the intensity signal, while target ranging can be performed accurately by referring to the phase shift (<1 mm to 10 m). The system can operate in total darkness.

The IVVS can be used in any field requiring viewing and inspection in hostile or hazardous environments, for example, civil protection, archaeology or for geological surveys.

Scanning head of the IVVS

High-precision metrology for large plants

The construction and management of the experimental plants has required the development of high-precision optic metrology methods. These methods permit the control of objects through comparison of their real characteristics with those defined by CAD models, through dynamic measurements of the objects in movement, their alignment and reverse engineering.

Different systems are used, both for fusion plants and for applications outside fusion.

In fact, these systems can be implemented in large plants requiring high-precision inspection, for example, in shipyards and large manufacturing machines. They have already been used to inspect the prototype of the ITER toroidal magnet coil, for the alignment of the magnet of the Elettra synchrotron at Trieste, for the five-module robot of the ITER in-vessel penetrator, for the alignment of the remote manipulators in FTU and the alignment of the manipulator used to install and remove the ITER divertor.

Inspection of the prototype coil for the ITER toroidal magnet

Alignment of the magnets at the Elettra synchrotron of Trieste

Neutron generators

RADIATION SOURCES

The Frascati neutron generator (FNG) designed and built by ENEA is a continuous, nearly isotropic point source producing 10^{11} neutrons/s with an energy of 14 MeV through the T(d,n)α fusion reaction. A deuterium ion beam is accelerated up to 300 keV and then focussed on a target containing tritium. It is also possible to generate 2.5-MeV neutrons by using a target containing deuterium; in this case, the neutrons are produced through the D(d,n)^{3}He fusion reaction and have an intensity a hundred times lower than the 14-MeV neutrons because of the smaller cross section of the D-D reaction.

The laboratories attached to the facility are equipped with instrumentation for neutron-activation measurements, thermoluminescence dosimetry, spectroscopy with scintillation counters, gamma- and beta-ray spectroscopy.

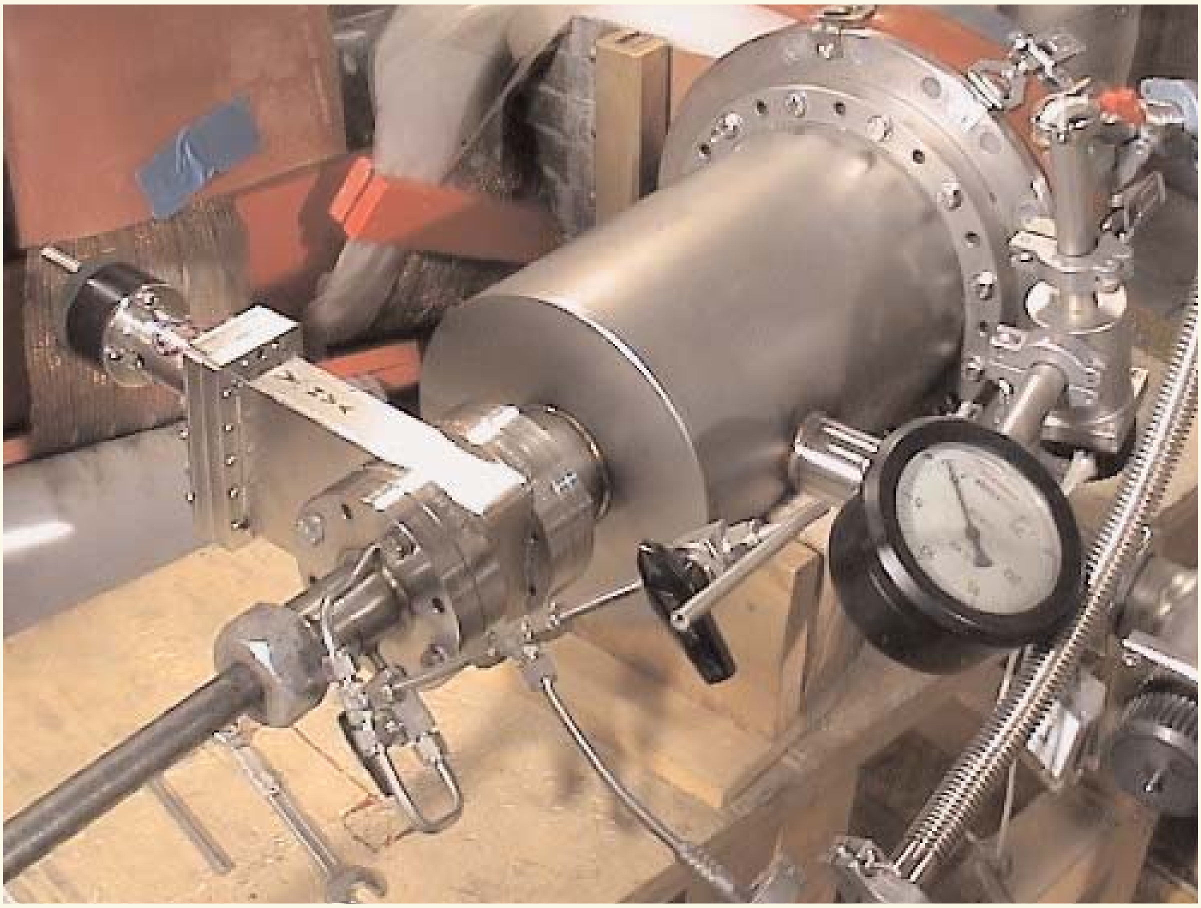
The facility is used for experiments to validate nuclear fusion data. However, irradiation is also carried out for application in other fields such as astrophysics and high-energy physics (for the calibration and characterisation of measuring instruments), for the study of radiation damage to electronic and microelectronic components and for neutron dosimetry. Other potential applications concern analyses in the presence of elements, even trace elements, in materials by the neutron activation method, and dating of archaeological material by thermoluminescence dosimetry.

Frascati neutron generator

Plasma focus

The plasma-focus device generates a pulse of neutrons onto a system of two cylindrical coaxial electrodes placed in a vacuum chamber containing a suitable gas mixture. Depending on the type of gas used, different types of radiation – neutrons, x-rays, highly collimated ion and electron beams - can be emitted during a series of very short shots (~100ns).

The plasma focus is a technologically simple and flexible device and has several interesting advantages: it is intrinsically safe with regard to radioactivity (emitted only during the very short pulses), the source-intensity/emitted energy ratio is optimum, construction and operation costs are limited due to the relatively small size, which also facilitates its transport.



In collaboration with the Universities of Ferrara and Bologna, ENEA developed a 6-kJ 21-kV plasma focus, which has also been used to study and patent applications in industry and medicine. The 2.5 or 14-MeV neutron emission makes it possible to measure the presence of even trace elements in materials by the neutron activation method. This technique is of interest to the field of mineral surveying, as the composition of a sample can be quickly determined and hence also the economics of its extraction/processing.

The emission of fast ions with an energy of some MeV can be advantageous to metallurgy for steel and titanium-alloy hardening processes through ion and nitrogen implantation. Compared to other types of ion implanters, the plasma focus is easier to operate, for example, at lower vacuum values. With regard to medical diagnostics, the possibility of exploiting the neutron emission to produce short-life radioisotopes for therapy and diagnostics based on positron emission tomography (PET) is under study.

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